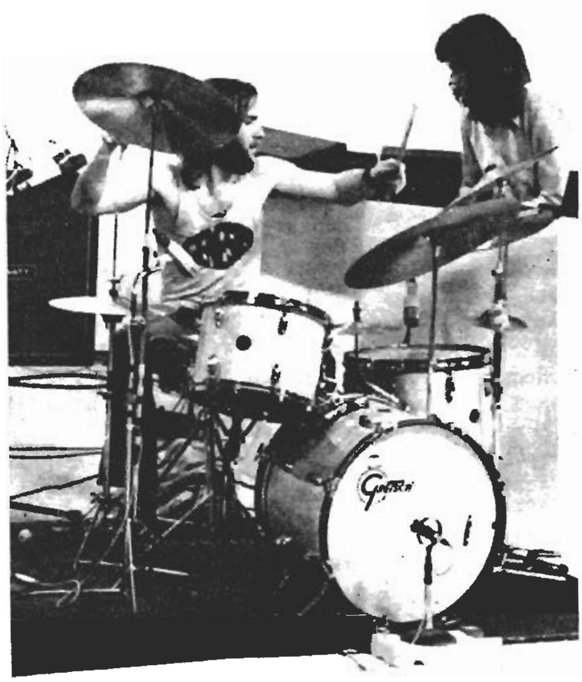
By Sidney L. Silver

THERE is a growing awareness of the problem of hearing loss among young people whose ears are constantly being subjected to more loud music than they can safely tolerate. Part of the difficulty comes from frequent attendance at live rock concerts where the intense sounds of electronically amplified musical instruments assault the ears of the audience. In addition there is the tendency of many youngsters to listen to recorded rock music at unreasonably high sound levels over long periods of time (especially on earphones) which can also contribute to impairment of the hearing mechanism. Members of rock groups experience still higher sound levels in both practice and performance sessions so they can be expected to face more significant hearing loss hazards.

It is now recognized that prolonged exposure to high-intensity sounds is a serious form of noise pollution which can lead to irreversible hearing damage. Unfortunately, there is a still widely held and erroneous belief that hearing loss sustained by exposure to excessively loud music is insignificant, or at worst only temporary. The facts tell a different tale: the temporary hearing loss suffered by individuals exposed to intense sounds may become permanent after repeated exposure. Gradually, the noise-induced hearing loss accumulates over the years and usually goes unnoticed until it becomes great enough to offset the ability to understand speech. When this happens, the loss is permanent and cannot be corrected by any treatment known to medical science.

The fear exists that as more and more young people are exposed to intense sound levels, many of them will eventually suffer sufficient hearing damage to jeopardize their occupational potential. In addition to the problem of accelerated deafness, there is mounting evidence that excessive noise exposure can cause severe psychological and physiological damage as well.

Nature of the Problem. The term "noise" is usually applied to unwanted or undesir-



ROCK MUSIC & Noise Pollution

Prolonged exposure to high-intensity sounds can lead to irreversible hearing damage

able sound. But this definition must allow for a very wide reaction by different people to the same sound. Depending upon the degree of pitch distribution, intensity, and persistence, certain sounds may be objectionable to some individuals but a source of pleasure to others. For example, the sound of modern pop music may be agony to some adults but ecstasy to most teenagers, the difference reflecting a conflict in musical tastes. In the case of hard rock, loudness is one of its identifying characteristics, and the acoustic noise produced is an element designed to heighten the aesthetic experience for the listener.

For many rock music fans, the ultimate listening pleasure is one in which sound intensity becomes so penetrating that it assumes complete control over mind and body. This demands a kind of total audience involvement in which the sensual impact of the ambient sound pressure levels is primarily intended to be felt rather than heard.

Unfortunately, repeated exposure to these intense sounds has proven disastrous to sensitive ear drums and damaging to the nerve cells of the inner ear. At the present time, however, there is still no general agreement as to exactly how much noise and what duration of exposure constitute a health hazard.

Super-Amplified World of Rock. Imagine being exposed continuously to the sound pressure levels created by a 100-piece military band playing fortissimo passages at close quarters, or the crescendo of street noises produced by a team of jack hammers operating simultaneously, or even the incessant roar of jet airplanes at a busy airport. The acoustic power generated by any of these sources roughly corresponds to the ultra-high levels associated with live rock groups aided by powerful amplification systems. In Fig. 1 is shown how other environmental noises compare with the high-intensity sound of a typical electrified rock band.

One important aspect of noise pollution

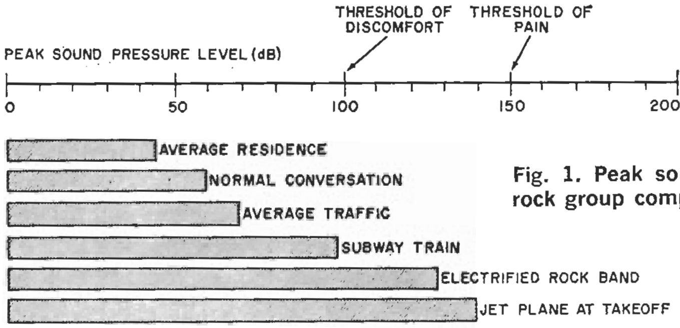


Fig. 1. Peak sound pressure level of typical rock group compared with other noise levels.

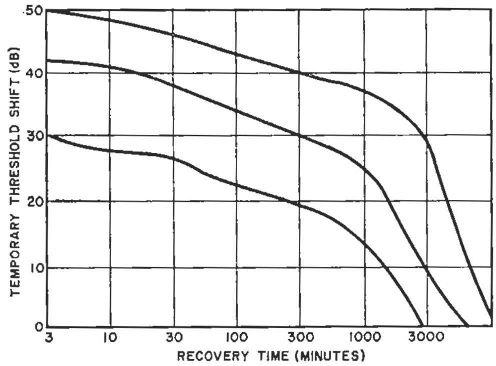
is the increase in rock music activity at leading concert halls which are primarily identified with classical music. Many of these halls were designed to provide programs of "natural" music without benefit of amplification, or in other cases, some degree of electronic enhancement to optimize the sound quality. These techniques range from simple sound reinforcement systems for providing uniform coverage throughout the hall to highly sophisticated systems for electronically controlling the total acoustical environment. But even a properly controlled system cannot compensate for the disturbing ringing and howling of hard rock music, so dominant that the sound level of a moderately loud rock band would be comparable with the screech of a jet fighter plane. With rock music, the delicate balance of hall size, reflecting surfaces, and instrument volume become grossly distorted by the crescendo of escalating decibels emitted by the high-powered electronic gear associated with rock groups.

Today, almost any musical instrument, from the drum to the sitar, can be enhanced electronically either through new instrument design or by adding internal pickups to each instrument and feeding the audio signals to separate high-power amplifiers and speakers. The amplifying systems then become part of the program source, not only emphasizing the volume but also contributing an array of effects such as tremolo, vibrato, reverberation, etc., to modify the tonal color. In many cases, the individual instrument competes for the decibel by feeding its own amplifier system, each amplifier ranging up to 100 or even 300 watts output.

For live performances, these instrument amplifiers are usually reamplified by a public address system, thus pumping into the combined speaker systems totals of more than 1000 watts of electrical power. Not to be left out, vocalists work close to their microphones and override the amplified instrument sounds with separate amplifiers. At outdoor concerts, it is not uncommon for rock groups to use huge amplifier systems that push more than 2000 watts through massive theater-type horn speakers.

Equipment produced for amplifying musical instruments should not be confused with entertainment hi-fi systems that are designed to faithfully reproduce sound from various program sources with an absolute minimum of distortion. Instrument amplifiers are noted primarily for their sophisticated electronic gadgetry which rock groups use to create an endless stream of controlled-distortion effects. The output power generated by these devices is considered unsafe for prolonged exposure. Manufacturers of this high-powered gear are well aware of the hearing hazards involved, else they would not put on their equipment such warnings as: *"Caution: Repeated exposure to high sound levels (more than 80 dB) may cause permanent impairment of hearing."*

Fig. 2. Recovery times from temporary threshold shift for three listeners exposed to pressure level of 105 dB.



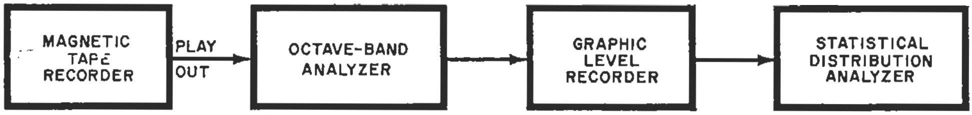


Fig. 3. Measurement system uses statistical approach for evaluation of musical sounds.

One of the effects in the rock music repertoire, known as "fuzz-tone," deliberately distorts the music by shunting the audio signal with a full-wave rectifier at a high-level stage in the amplifier. This eliminates the positive or negative portions of the audio waveform and completely "muddies" the original sound. Then there are the electric guitar "wah-wahs" used to synthesize tones similar to those of the trombone or trumpet. Cross-product distortion is also deliberately introduced by holding the instrument so that certain notes go toward the speaker system and regulating the feedback with a special gain control on the instrument so that several notes can be produced simultaneously, plus the sum and difference frequencies. Still another addition to the sonic boom consists of a pickup microphone attached to any wind instrument, with the amplifier adjusted for a number of tonal variations. Thus, one musician can produce up to four tones at the same time; one octave higher, one or two octaves lower, or any combination with the original tone at any relative sound level.

It must be emphasized at this point that it is not the electronically enhanced instruments themselves that pose the risk of hearing damage. The culprit is the excessive sound pressure levels produced by the electronic systems. At the other end of the scale, electronic modification of musical instruments can provide an almost unlimited variety and combination of effects to enhance the beauty of music. Creative musicians, both pop and progressive, are constantly searching for new sounds and are more concerned with exploring changes in harmonic overtone structures than the production of ear-splitting volume.

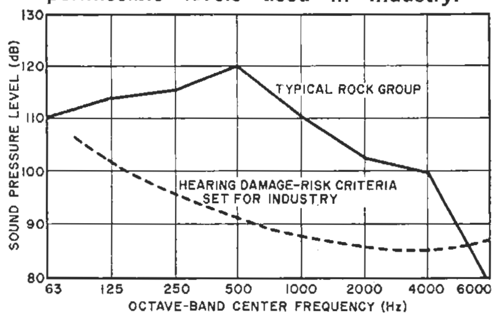
Human Response to Intense Sound. High-intensity sound like that produced by rock groups may affect hearing in a number of ways that are broadly classified as temporary threshold shift (TTS), permanent threshold shift (PTS), and acoustic trauma, the order indicating the general degree of severity of the noise exposure.

TTS is a relatively short-term effect in which exposure to loud sounds raises the threshold of hearing. It temporarily reduces the ear's ability to hear faint sounds. The higher the level of sound and the longer the exposure, the greater the shift in threshold. For example, when individuals are continuously exposed to live rock music, the most common symptom is a prolonged dullness in hearing or in some cases a maddening "ring" in the ears (tinnitus). This is somewhat analogous to the temporary impairment in visual acuity following the triggering of a flashbulb.

Sound components with maximum energy concentrated in the low-frequency range produce less TTS than those sounds concentrated in the high frequencies. So, a loud rumbling sound is less dangerous to the ears than is a screeching sound. If the exposure to intense musical sound is brief, the TTS will gradually diminish until some of the acoustical fatigue disappears. But complete recovery may take hours or even days. As a general rule, sound levels below 80 dBA (80 dB on the A-weighted scale of a sound-level meter) do not produce significant TTS; higher levels may produce shifts as great as 50 dB.

The recovery patterns of several individuals exposed to mid-band noise at a 105-dB sound pressure level for a period of 90 minutes are shown in Fig. 2. Here 0 dB represents the normal hearing thresholds established by audiometric measurement prior to exposure. In each case, the hearing response after exposure was taken at 4000 Hz where the human ear is par-

Fig. 4. Octave-band levels of typical rock group compared to 8-hr maximum permissible levels used in industry.



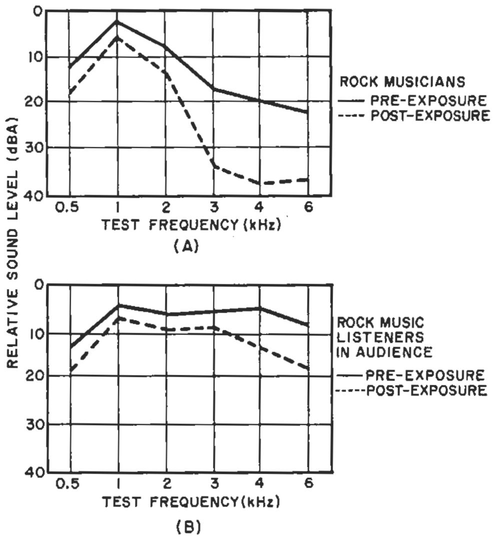


Fig. 5. Hearing levels after a 3-hr session; average sound level 112 dBA.

ticularly vulnerable to TTS. It can be seen that the initial hearing loss as well as complete recovery time varies widely among the listeners.

A point to consider is that, when intense musical sounds are interrupted, the ear can rest and partially recover from the effects of the noise. Due to the intermittent nature of most live rock music performances, the risk of hearing damage is somewhat reduced. These periodic interruptions, including intermission time, permit the ear to tolerate the sound for a longer duration and, hence, result in partial recovery from auditory fatigue. Nevertheless, repeated exposure to sound levels greater than 80 dBA over a prolonged time, not followed by adequate recovery time between exposures, will eventually lead to partial deafness or permanent threshold shift.

The onset of permanent damage is characterized by a fairly predictable sequence of events. Musicians, audiophiles, and other critical music enthusiasts would probably be the first to note a loss of hearing acuity for high-pitched sounds like the overtones produced by a violin or piccolo. The presence of these overtones gives character and quality to music and enables the listener to distinguish between instruments in the higher frequency range.

If the damaging exposure continues, permanent hearing loss will eventually be extended to the mid-frequency range that is most important for understanding speech. At this stage, when the hearing loss affects the ability to conduct verbal conversations under everyday conditions, nothing can be done to reverse the condition. Profound deafness or total loss of hearing due to continuous exposure over many years must be regarded as unusual, but there is no reliable way to predict which musicians or listeners might suffer impairment.

Measurement Procedure. In measuring musical sound levels, instrumentation tape recorders provide a means of obtaining a large amount of data that can be analyzed in an acoustic laboratory. These recorders are usually provided with two input channels, one accepting the output of a sound level meter and the other feeding a separate voice track for marking and identification purposes. Included in the measuring system is a sound level meter calibrator that supplies a frequency of precisely known sound pressure level to the pickup microphone and makes possible the recording of a reference signal. To handle the wide range of signal levels encountered in noise measurement, an accurate step attenuator is incorporated in the tape recorder to shift the recorded calibration signal to any convenient level so that any differences in the setting of the attenuator can be related to various playback level adjustments.

In the lab, a sample of recorded music is played through an octave-band analyzer that electronically separates the acoustic energy into identifiable frequency bands. As shown in Fig. 3, the analyzed output is fed to a graphic level recorder to provide a continuous written record of the data as a function of time. It is often convenient to extend the graphic recording of the sound level by statistical techniques to evaluate the music sounds automatically in terms of duration of sound energy. For this purpose, a statistical distribution analyzer presents a numerical display of the recorded information simultaneously with the writing process in the level recorder.

A plot of the octave-band analysis of sound pressure levels produced by a typical live rock music group is shown in Fig. 4. For comparison, the octave-band levels are given for the maximum permissible exposure limit, equivalent to 90 dBA, specified by federal regulations for industrial noise exposure during an eight-hour workday.

Accordingly, the interval of exposure can be increased by 5 dB for each halving of the duration of exposure without increasing the risk of noise-induced hearing loss. Thus, for a sound level of 95 dBA, the exposure must not exceed four hours per day, and for a level of 115 dBA, it must not exceed more than 15 minutes per day. Clearly, the sound levels generated at live rock concerts are well above the hearing conservation limits set for industry.

Noise Exposure Tests. Unfortunately, the relationship between temporary and permanent hearing loss cannot be determined directly in humans because the inner ear is a delicate area that is almost totally inaccessible for examination. It is necessary, therefore, to use experimental animals. In a recent experiment, researchers at the University of Tennessee exposed guinea pigs to recorded rock music at the approximate peak sound pressure level of 120 dB likely to be encountered in a rock music hall. Listening sessions were spread over a period of three months at intervals designed to match the listening habits of the average rock music buff. At the end of this period, the inner ear cells were exposed to microscopic examination where they clearly revealed the effects of cell destruction in the cochlea which translates sound waves into nerve impulses.

The Public Health Service has been collecting data from sample observations of rock music levels in order to determine the effects on the hearing of rock group members and individuals attending rock sessions. In a typical sample taken during a teenage rock session (see Fig. 5), the sound levels averaged 112 dBA and were fairly uniform throughout the hall. The hearing levels of the musicians and a group of audience listeners were determined by audiometric measurements just before and immediately after the three-hour rock concert. According to Fig. 5A, the pre-exposure levels of the rock group members show a greater average hearing loss as compared to the listeners as shown in Fig. 5B, due no doubt to their more frequent exposure to high-level sound. Both cases, however, show significant temporary threshold shifts as indicated by marked differences between pre- and post-exposure hearing levels.

Repeated exposure to live rock music is only one aspect of over-stimulation of the human ear experienced by those people engaged in recreational activities. In assessing the risk of hearing damage, due consideration must be given to the accumulation of numerous other sources of noise pollution encountered in everyday modern living in both social and industrial environments. ◈